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B. T. GALLOWAY, *Chief of Bureau.*

THE VALUE OF FIRST-GENERATION HYBRIDS IN CORN.

BY

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., July 5, 1910.

SIR: I have the honor to transmit herewith a paper entitled "The Value of First-Generation Hybrids in Corn," by Mr. G. N. Collins, a Botanist of this Bureau, and recommend its publication as Bulletin No. 191 of the Bureau series.

This report shows how the vigor and fertility of hybrids may be utilized to increase the yield of the corn crop, in addition to other factors of adaptation and breeding.

Respectfully,

WM. A. TAYLOR,
Acting Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

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THE VALUE OF FIRST-GENERATION HYBRIDS IN CORN.

INTRODUCTION.

The use of first-generation hybrids offers one of the most promising methods of increasing the yield of corn. The evidence that crossing can in general be relied upon to give an immediate increase of vigor and productiveness appears conclusive, yet the practice seems never to have been applied on a commercial scale. The plan of utilizing first-generation hybrids involves the making of the cross anew each year, and this is readily feasible with corn. Many efforts have been made to develop hybrid varieties, but the increased vigor and productiveness that result from hybridization appear to be confined largely to the first generation and to disappear gradually in later generations.

The present paper reports experiments with a series of first-generation hybrids between widely different types of corn and brings together the results of previous experiments. Investigations that warrant the placing of confidence in this method of increasing the yields of corn are scattered over a long period of years, and most of them appear to have been made in ignorance of similar work previously reported. Individual experiments taken alone have not made it perfectly clear that the results were not accidental, but the assembled evidence forces the conclusion that the increases secured in the first generation by crossing varieties can be made a factor of production comparable in importance to breeding.

It was indicated more than three decades ago that seed produced by crossing two varieties of corn could be relied upon to produce larger crops than the parents, and that this increase was to a great extent lost in following generations.

At about the time when it was discovered that an increase in yield and vigor followed the crossing of two varieties, the attention of investigators was attracted to the possibility of the improvement of corn through what then appeared the more scientific methods of selection. The latter idea was in accord with the most advanced ideas of evolution, while the former appeared as an isolated fact discovered by accident.

It was natural that investigators should follow out what appeared to be the more logical and scientific method. The fact that yields could be materially increased by simply crossing two varieties was lost sight of. Great strides have been made in the knowledge and possibilities of corn improvement by selection, but until the past few years the possibility of utilizing the vigor of first-generation hybrids of corn has remained almost exactly where it was left by the pioneer experimenters.

PECULIAR HABITS OF THE CORN PLANT.

Even after the increased vigor of first-generation hybrids became recognized as a general principle it was not appreciated that the peculiar habits of the corn plant made its commercial application to this crop entirely feasible. Corn is peculiar among the important crop plants in being wind-pollinated and in having the male and female flowers on widely separated parts of the plant. This combination of characters permits the production of crossed seed in large quantities by the simple expedient of planting two varieties together and removing the tassels from the plants of one variety, which will then produce only hybrid seed. The importance of this fundamental difference between the flowering habits of corn and those of other crops has not been sufficiently appreciated. Systems of breeding developed for other plants have been applied to corn, diverting attention from this more simple method of improvement made possible by the peculiar habits of the plant. The use of first-generation hybrids will doubtless be found applicable to other crops, but in few will its utilization be so easily accomplished as with corn.

FIRST-GENERATION HYBRIDS CONFUSED WITH HYBRID VARIETIES.

The utilization of crossing as a means of securing increased yields was further retarded by the failure to realize that the high performance of the generation immediately following a cross is not maintained in subsequent generations. Much effort has been expended in attempting to establish hybrid varieties, overlooking the possibilities of the direct use of hybrid seed of the first generation. The fact that few of the hybrid varieties have been found to have permanent value should not prevent the appreciation of the vigor that immediately follows the crossing.

Until recently hybrids were usually made by hand-pollination and the quantity of first-generation seed was necessarily small. That the plants from this seed were especially vigorous and productive aroused the hope that a happy combination of varieties had been discovered, and attention was at once centered on the increase of the

stock and its further improvement. In the succeeding generations diversity appeared and before the desired uniformity could again be secured through selection the increased vigor resulting from the crossing had disappeared.

VIGOR OF HYBRIDS A FACTOR OF PRODUCTION.

Comparatively few recent experiments with a direct bearing on the value of first-generation hybrids have been reported, but all that have been made confirm the earlier results. Taken in connection with the experiments to be reported in the present paper they establish beyond question that the vigor of first-generation corn hybrids is a means of securing increased production that is capable of a very wide application. As soon as the general public becomes acquainted with such a simple and inexpensive means of increasing the yield of this most important crop, a rapid extension of the practice should follow. The great need is for detailed information regarding the particular varietal combinations best adapted to the different local conditions. At present the data are so meager that experiments must proceed empirically, but the lack of detailed information should not obscure the importance of the subject nor stand in the way of utilizing the results already accomplished.

While it would appear safe to recommend this method to all corn producers, the object of the present bulletin is rather to urge the inauguration of experiments in as many parts of the country as possible. It is much as though the possibilities of increased yields through the application of commercial fertilizers were still unappreciated by the general public and experiments to prove their efficacy were being conducted in a few isolated localities. Indeed, the utilization of first-generation hybrids appears to have more general application than the use of commercial fertilizers, but the need for experiments under a wide range of conditions is equally great. As in the use of fertilizers, conditions may perhaps be found where the increase from crossing will be slight or none at all, but even this result should not detract from the fact that under most conditions the increases are significant.

POPULAR BELIEF IN THE SUPERIORITY OF FIRST-GENERATION HYBRIDS.

Though the possibility of utilizing the vigor of first-generation hybrids is only beginning to be appreciated from the scientific standpoint, the increased yields that result from crossing have probably been utilized unconsciously since prehistoric times. It is a regular custom among many native American tribes to carefully plant seeds of different varieties in each hill of corn. This is done for the purpose

of increasing the yield. Though the expected increase is usually associated in the minds of the natives with superstitious ideas regarding sexuality in the plants, the vigor secured by such crosses may well have been an important factor in establishing this custom with primitive tribes.

The value of first-generation hybrids is further recognized in a widespread belief among practical seed growers that the plants produced by accidental crosses of pure strains are often exceptionally vigorous. The following statement from Dr. W. W. Tracy, who has had a wide experience in the practical breeding of plants and in commercial seed production, voices this belief:

> The second step is the selection of a few plants which shall come as near to the ideal as possible and the saving of the seed of each of these separately. I recommend this instead of selecting the *best one* because it often happens that the very best plant is in reality a crossed one which owes its superiority to a cross of some exceptionally vigorous but otherwise inferior plant, and this "bar sinister" will be revealed in the inferior quality of plants grown from its seed.[a]

PREVIOUS EXPERIMENTS WITH FIRST-GENERATION HYBRIDS.

EXPERIMENTS IN MICHIGAN.

That the immediate result of crossing two varieties is to increase the yield was shown by definite experiments as early as 1878 by Dr. W. J. Beal, of the Michigan Agricultural Experiment Station. The plan for such experiments had been outlined two years before, in 1876, the same year that Darwin published his classical work on self and cross fertilization in plants, but without knowledge of Darwin's results. Doctor Beal's first statement was as follows:

> To improve or infuse new vigor into varieties (or races I should more properly call them) I propose in case of corn and some other seeds to get seeds from remote parts where it has been grown for some years, and plant near each other and mix them.[b]

Even at this early date Doctor Beal appreciated the fact that the benefits were largely confined to the first generation.

> The good results of such crossing will last for several years, though most apparent the first year.[c]

The nature of the first experiment and its relation to the similar experiments of Darwin are shown in the following quotation:

> From several different sources in remote parts of our State I obtained white dent corn and yellow dent corn for seed. So far as possible I obtained good seed from men who had raised the corn for ten or more years in succession on the same farm.

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[a] Tracy, W. W. Importance of Uniformity of Varietal Character in Vegetable Seeds. Market Growers' Journal, October 30, 1909, p. 2.

[b] Beal, W. J. Report, Michigan Board of Agriculture, 1876, p. 206.

[c] Loc. cit.

I crossed some white dent from one locality with pollen from white dent obtained in a remote locality. This may add vigor to the race, though it will probably not otherwise change the race. The plan was conceived by me about a year ago, and several months afterwards the same kind of experiments were reported on many species of plants by Mr. Charles Darwin, of England. The favorable results of many experiments there given are quite remarkable.[a]

In 1880 the representatives of five different agricultural schools entered into an agreement to test by a uniform experiment at their several stations this method of corn improvement. Each experimenter was to report his experiment to the other parties to the agreement.

The details of this agreement are given as follows:

Each man in his own State shall select two lots of seed corn which are essentially alike in all respects. One should have been grown at least for five years (better ten years or more) in one neighborhood and the other in another neighborhood about 100 miles distant. In alternate rows plant the kernels taken from one or two ears of each lot. Before plowing, thin out all poor or inferior stalks. As soon as the tassels begin to show themselves in all the rows of one lot, pull them out, that all the kernels on the ears of those rows may certainly be crossed by pollen from the other rows. Save seed thus crossed to plant the next year by the side of seeds of each parent. Seeds of one parent can be obtained from the rows not topped. Seeds of the other parent should be planted by themselves to get pure seeds of the same year.

For the second year, select two pieces of ground, each as even as possible, about 4 by 8 rods in extent. Manure it evenly as possible with barnyard manure if any fertilizer is employed. Plow the ground without bed or ridge furrows or, if either occur, plant so that a row of each comes at equal distance from the ridge or bed furrow. Take no unusual pains to make the ground very rich or to cultivate better than usual. Keep the cultivation alike on all parts of the plats as nearly as possible.

On one of these plats plant some of the cross seeds in alternate rows with seeds of one of the parents. On the other plat plant the crossed seeds in alternate rows with the other parent. Seeds of each parent raised the previous year will thus be tested with seeds of the same age from the cross. Take notes of the time in which the plants in each row come up and of the appearance from time to time. Make plats of the corn and be careful to keep everything straight. Take notes of the time of maturing, and when matured cut near the ground the hills of each row and shock separately. After it is cured, husk and weigh the ears and the stalks separately of each row. It would be well to weigh the dried shell corn of each row separately. In the report give the weight of corn and stalks of each row separately, then a summary of the weights of each parent and the crossed stalk. Each experimenter shall report his experiments thus made to each of the other persons entering into this arrangement.

A similar experiment was made at the agricultural college in 1878. In this the advantage shown by crossing of corn over that not crossed was as 151 exceeds 100, and in the case of black wax beans it was as 236 exceeds 100. In a similar experiment made during the past two years at the agricultural college, the corn from seed of crossed stock exceeded that not so crossed as $109\frac{67}{100}$ exceeds 100, or nearly 10 per cent in favor of crossed stock. The experiment was quite carefully made and I do not consider this result as purely accidental.[b]

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[a] Beal, W. J. Report, Michigan Board of Agriculture, 1877, p. 56.

[b] Ibid., 1880, pp. 287–288.

After a lapse of more than thirty years it is hardly possible to improve or refine the method of experimentation as outlined by this pioneer. His method of comparing yields by alternate-row plantings was also more perfect than that of his successors and is again coming into use as the best that has yet been devised.

In 1881 Doctor Beal made another cross, between two varieties from Oakland and Allegan counties, respectively, and reported the results of the cross as follows:

> The Oakland County seed corn was the better of the two. Owing to an accident we failed to raise any pure Allegan County seed in 1881. The "crossed corn" was only compared with pure Oakland County seed raised last year at the college.
>
> In the spring of 1882, on good soil in a portion of the vegetable garden, three rows of "crossed seed" were planted in rows alternating with three other rows of pure Oakland County seed of 1881. By an oversight each row of each lot was not kept separate. The pure seed yielded 57½ pounds in the ear; the "crossed seed" yielded 69½ pounds in the ear. In other words, the crossed stock exceeded the pure stock as 121 exceeds 100, nearly.[a]

EXPERIMENTS IN INDIANA.

Of the five cooperators entering into the agreement with Doctor Beal to test first-generation hybrids, Prof. C. L. Ingersoll, of Purdue University, seems to have been the only one who reported results. In this case it appears that seed of the variety detasseled was not saved, so that the hybrid was compared with only the male parent. Since in this case the cross was made between two strains of the same variety, this failure does not entirely vitiate the results. The experiment is reported as follows:

> I took corn from Delaware County and also from Switzerland County, in this State, and planted as in first year's directions.
>
> The tassels were removed from the Delaware County corn, so that it was certainly fertilized by pollen from the Switzerland County corn. Both were a white dent variety. The result of corn raised was as follows:
>
> Delaware County (hybrids), 122 pounds, 27.89 bushels per acre.
>
> Switzerland County, 63 pounds, 14.40 bushels per acre.
>
> Switzerland County (alone), 72 pounds, 16.46 bushels per acre.
>
> These results, although small, seem to show that in this instance at least, and with the experiment half completed, there is a marked difference in cross-fertilized and self-fertilized corn when the seed from the crossing is obtained from widely separated localities and is of the same variety.[b]

It seems that the experiment was again attempted two years later[c] and hybrid seed was secured, but subsequent reports of the university do not show that the experiment was ever completed, Professor Ingersoll having left the institution.

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[a] Beal, W. J. Report, Michigan Board of Agriculture, 1881–2, p. 136.

[b] Seventh Annual Report of Purdue University for 1881, p. 87.

[c] Ninth Annual Report of Purdue University for 1883, p. 72.

EXPERIMENTS IN MAINE.

The only reference by subsequent workers to Doctor Beal's experiments so far as we have ascertained is that of Prof. J. W. Sanborn in reporting a similar experiment in Maine.

Professor Beal found that outcrossed corn, as the average of two years of trial, gave as 131 is to 100 for inbred corn. I found the same result, or as 252 is to 179, and for fodder as 490 is to 350. The facts have a deep significance to our farmers.[a]

EXPERIMENTS IN ILLINOIS.

Nine years after the work of Doctor Beal and apparently in ignorance of his results, Mr. G. W. McCluer reported the results of a series of crosses made at the Illinois Agricultural Experiment Station. He did not give actual yields, but noted the average size of the ear as compared with that of the parents in 18 crosses comprising 14 different combinations of dent, pop, soft, and sweet corn. In 16 of the 18 crosses, or 12 of the 14 different combinations (2 were duplicates and 2 reciprocals), the ears of the first-generation hybrid were larger than an average of the parents, and in 4 of the crosses the hybrid ears were larger than those of either parent. One of the exceptions is stated to have been planted in an unfavorable location. The decrease in the other case was 4.6 per cent. The average increase in weight for the whole series was 14 per cent.

With respect to the uniformity of the first-generation hybrids, McCluer says:

During the first growing season the uniformity of the crossed plats was very noticeable. Of 142 plats planted with sweet corn, pop corn, and these crosses it is safe to say there was as much uniformity in any one of the crossed plats as in any, and very much more than was found in most, of the plats planted with pure varieties.[b]

The following year, 1891, a number of the ears from this crossbred corn were again planted and Mr. McCluer says:

Nearly all the corn grown a second year from the crosses is smaller than that grown the first year, though most of it is yet larger than the average size of the parent varieties. The cause of this apparent decrease in size, as compared with the previous year, can only be guessed at. It can not be attributed to the season, because the Queen's Golden–Common Pearl pop corn and Gold Coin–Flour corn crosses grown in 1891 show as large a proportionate increase in size of ear as is shown in any of the crosses grown in 1890. There is probably a strong natural tendency in the crosses to revert to the size as well as the form of the parent types. This is shown in the Leaming sweet-corn crosses, in which the corn reverting to the dent is larger than that reverting to the sweet types. Or the loss of size may be due to a diminution in some way of the vigor imparted by crossing.[c]

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[a] Sanborn, J. W. Indian Corn. Agriculture of Maine, Thirty-Third Annual Report, Maine Board of Agriculture, 1889–90, p. 78.

[b] McCluer, G. W. Corn Crossing. Bulletin 21, Illinois Agricultural Experiment Station, 1892, p. 85.

[c] Op. cit., p. 96.

In view of the interest that attaches to these early experiments, Mr. McCluer's tabulated results are given as follows:

TABLE I.—*Results of Mr. G. W. McCluer's experiments with corn hybrids at the Illinois Agricultural Experiment Station, showing the effect on the size of ear.*

Cross.	Weight of 10 ears of the male variety.	Weight of 10 ears of the female variety.	Average weight of 10 ears of the two parent varieties.	Weight of 10 ears grown from cross the first year.	Weight of 10 ears the second year after the cross, ounces.
White dent—Queen's Golden	81	34.5	57.75	76	Ears like the dent type 64 Ears like the pop corn type 52.5
Queen's Golden—White dent	34.5	81	57.75	64	Ears like flint corn 55 Ears like pop corn type 47.5
Black Mexican—Queen's Golden	36	34.5	35.25	47.5	Types not separated 43.5
Queen's Golden—Common Pearl pop corn.	34.5	27.5	31	42	Not grown a second year.
Leaming—Mammoth	87.5	61.5	74.5	91	Corn grown from yellow dent kernels 86 Corn from white dent kernels 90 Corn from sweet kernels 74
Leaming—Mammoth	87.5	61.5	74.5	82	Not grown a second year.
Leaming—Mammoth	87.5	61.5	74.5	80.5	Not grown a second year.
Leaming—Triumph	87.5	46.5	67	83	Corn from dent kernels 86 Corn from sweet kernels 68
Leaming—Eight-rowed	87.5	41	64.25	72	Corn from white dent kernels 80 Corn from yellow dent kernels 75 Corn from sweet kernels 58
Gold Coin—Flour corn	63	39	51	78	Has not yet been grown a second year.
Black Mexican—White dent	36	81	58.5	51	From flint kernels of flinty ears 53 From flint kernels of sweet ears 40 From sweet kernels of flint ears 39 From sweet kernels of sweet ears 38.25
Stowell's—Eight-rowed	57.5	41	49.25	47	From selected ears 49 From self-fertilized ears 38 From cross-fertilized ears 43
Stowell's—Triumph	57.5	46.5	52	52.5	From self-fertilized seed 31 From cross-fertilized ear 48.5 Do 41 Seed from selected ears 54 Seed from self-fertilized ears 39
Stowell's—Mammoth	57.5	61.5	59.5	61	Self-fertilized ear, plat 88 43 Self-fertilized ear, plat 76 52 From cross-fertilized ear, plat 86 55 From cross-fertilized ear, plat 87 45.5 Seed from selected ears 55
Stowell's—Gold Coin	57.5	62.5	60	62.5	From self-fertilized ear, plat 89 48 From self-fertilized ear, plat 90 54 From self-fertilized ear, plat 91 54 Seed from selected ears 58 Seed from self-fertilized ear 48
Gold Coin—Triumph	62.5	46.5	54.5	58.5	From cross-fertilized ear, plat 93 56 From cross-fertilized ear, plat 92 50 Seed from selected ears 49
Gold Coin—Eight-rowed	62.5	41	51.75	56	Seed from selected ears 50
Gold Coin—Eight-rowed	62.5	41	51.75	58	Not grown a second year.

The table further shows the marked decrease in size of ear in the hybrids that follows even one generation of self-fertilization. There is, however, so much "splitting" in the type of the ears in the second year that their size, as compared with those of the second generation, can not fairly be expressed in averages.

The following year, 1892, Morrow and Gardner, also at the Illinois station, reported the results of tests of five first-generation hybrids compared with their parent varieties.[a] In all cases the yield of the cross was greater than an average of the parents and in three cases it exceeded that of either parent. Stated in bushels, the increases above the average of the parents ranged from 1.2 bushels, or 1.9 per cent, to 17.2 bushels, or 28 per cent, the average increase being 13.8 per cent. The average increase of the crosses over the highest yielding parents was 4.66 bushels per acre, or 6.5 + per cent. The comparisons were apparently made in $\frac{1}{40}$-acre plats. The results of the experiment are shown in Table II.

TABLE II.—*Results of experiments by Morrow and Gardner with corn hybrids at the Illinois Agricultural Experiment Station in 1892.*

Variety.	Yield per acre.	
	Number of ears.	Air-dry corn.
		Bushels.
Burr's White	9,960	64.2
Cranberry	9,200	61.6
Average	9,580	62.9
Cross	7,080	64.1
Burr's White	9,960	64.2
Helm's Improved	10,880	79.2
Average	10,420	71.7
Cross	11,000	73.1
Leaming	10,440	73.6
Golden Beauty	8,280	65.1
Average	9,360	69.3
Cross	11,520	86.2
Champion White Pearl	11,080	60.6
Leaming	10,440	73.6
Average	10,760	67.1
Cross	8,760	76.2
Burr's White	9,960	64.2
Edmonds	9,040	58.4
Average	9,500	61.3
Cross	10,400	78.5

It will be noted that the crosses in this experiment were all between good-yielding varieties and apparently under favorable conditions. The relatively uniform results also indicate a small experimental error.

[a] Morrow, G. E., and Gardner, F. D. Field Experiments with Corn, 1892. Bulletin 25, Illinois Agricultural Experiment Station, 1893, pp. 179–180.

In the bulletin mentioned the practical possibilities of this method of increasing yields were indicated, as follows:

> The fact that increased yields can be obtained by crossing two varieties is pretty certainly established, and a few farmers are changing their practice accordingly. This is quite easily done by planting in one row one variety and in the next another variety, and removing the tassels of the one as soon as they appear. The ears forming on the rows having the tassels removed will be fertilized with pollen from the other rows, thus producing a direct cross between the two varieties. The seed should be selected from the rows having the tassels removed, and the experiments indicate that it will pretty certainly give a larger yield than the average of the parent varieties when planted under like conditions.[a]

The above quotation indicates that the authors considered the principle as established and worthy of practical application. No explanation has been offered why the matter was again allowed to rest at this point, but so far as can be learned no one has since practiced the growing of first-generation hybrids on a commercial scale.

In 1893 four additional crosses were planted, three of the four giving increases over the average of the parents, the average increase being 9.5 bushels, or 7.7 per cent. The results are shown in Table III.[b]

TABLE III.—*Results of experiments by Morrow and Gardner with corn hybrids at the Illinois Agricultural Experiment Station in 1893.*

Variety.	Yield per acre.	
	Number of ears.	Air-dry corn.
		Bushels.
Champion White Pearl	7,680	37.3
Burr's White	10,200	38.6
Average	8,940	38
Champion White Pearl—Burr's White Cross	7,080	28.4
Leaming (average 4 plats)	8,070	34.6
Burr's White	10,200	38.6
Average	9,135	36.6
Leaming—Burr's White Cross	9,480	41.7
Edmonds	7,740	28.3
Murdock (average 4 plats)	9,600	35.7
Average	8,670	32
Edmonds—Murdock Cross	9,840	41.4
Edmonds	7,740	28.3
Burr's White	10,200	38.6
Average	8,970	33.5
Edmonds—Burr's White Cross	9,360	37.8

The fluctuations in the yields of the different varieties and crosses in this experiment are so wide that little confidence can be placed in

[a] Morrow, G. E., and Gardner, F. D., loc. cit.

[b] Morrow, G. E., and Gardner, F. D. Experiments with Corn. Bulletin 31, Illinois Agricultural Experiment Station, pp. 359–360.

results. The omission of single members from the series would materially change the average. The lack of uniformity in the conditions is indicated by the great disparity between the yields of duplicate varieties in this experiment, which ranged as high as 15 bushels per acre.[a]

EXPERIMENTS IN NEW YORK.

After a further lapse of fifteen years, the subject was again approached from a somewhat different direction by Dr. G. H. Shull, of the Carnegie Biological Laboratory at Cold Spring Harbor, N. Y. In his first paper he suggests the possible use of first-generation hybrids in the following statement:

> The problem of getting the seed corn that shall produce the record crop, or which shall have any specific desirable characteristic combined with the greatest vigor, may possibly find a solution, at least in certain cases, similar to that reached by Mr. Q. I. Simpson in the breeding of hogs by the combination of two strains which are only at the highest quality in the first generation, thus making it necessary to go back each year to the original combination, instead of selecting from among the hybrid offspring the stock for continued breeding.[b]

The following year Doctor Shull stated his views in greater detail and reported on the result of crossing two closely related strains.[c] Before these results can be properly appreciated it will be necessary to briefly consider the problem from Shull's standpoint. It is considered that even the most nearly uniform varieties of corn consist of numerous strains, "elementary species" or "biotypes," all more or less mixed and hybridized. To this miscellaneous hybridizing Doctor Shull attributes the vigor and fertility of a variety. The method he suggests for the improvement of corn is to isolate the different strains and by making predetermined combinations to ascertain which will be the most favorable for agricultural purposes. It is fully recognized that isolating the pure strains or biotypes will very greatly reduce their vigor and yield, but by making a combination of the proper strains it is believed that the degree of fertility of the cross will reach that of the most productive plants in the original mixed strain and that an increase of the total yield can be obtained in this way.

Two self-fertilized strains which were separated from a common stock in 1904 and continuously self-fertilized since that time were reciprocally crossed in 1907. In 1908 the yields of these reciprocal crosses were compared with each other, with the self-fertilized parents,

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[a] Morrow, G. E., and Gardner, F. D., op. cit., p. 338.

[b] Shull, G. H. The Composition of a Field of Corn. Report, American Breeders' Association, vol. 4, 1908, p. 300.

[c] Shull, G. H. A Pure Line Method in Corn Breeding. Report, American Breeders' Association, vol. 5, 1909, p. 51.

and with crossbred stocks of the original variety. Reduced to bushels per acre and placed in tabular form, the yields reported by Shull were as follows:

Strain A, self-fertilized	23. 5 bushels.
Strain B, self-fertilized	25. 0 bushels (estimated).
A×B	74. 4 bushels.
B×A	78. 6 bushels.
General average of crossbred stock	75. 0 bushels.

From Doctor Shull's standpoint the important point in the above comparison is the increase of 1.5 bushels per acre which the average of the crossed pure strains shows over the average of the cross-pollinated original stock, an increase of 2 per cent.

At the same time a comparison was also made between the yield of self and cross pollinated ears of the same isolated strain. The yield from the cross-pollinated seed was 30 per cent greater than that from the self-pollinated ear. As an instance of the increased vigor of the first-generation hybrid this example is of interest, since it indicates that an increase in yield follows the crossing of even the most closely related plants.

To many producers of corn it will appear hardly practicable to apply this system on a commercial scale. Neither does it appear reasonable on theoretical grounds to look on these anomalous self-fertilized strains as representing the natural condition. It would seem that even the most advantageous combinations might be found without reducing the varieties to the verge of extinction before the cross is made.

But no method of investigation should be rejected for purely theoretical reasons. Until other experimental data are available the effect of previous breeding upon the vigor of the hybrids must remain an open question. The importance of the subject demands that all the phases shall be considered, and those who hold to the conception of "biotypes" and "pure germ cells" will do well to experiment along the lines suggested by Doctor Shull.

EXPERIMENTS IN CONNECTICUT.

A more extensive series of crosses was made by Dr. E. M. East at the Connecticut Agricultural Experiment Station. His results are stated as follows:

> The F_1 generation of 30 maize crosses were grown in 1908 on well fertilized land in Connecticut. They were planted 3 feet 6 inches each way, about four stalks to the hill. Seeds from the same parent ears[a] which were used to make the crosses were also grown for comparison. Only 50 hills of each of the crosses and of each parent could be grown on account of limited space, but the soil conditions were such that a

[a] "The parent ears were, therefore, one year older, but their germination was good, and their growth equal to inbred seed of the same ages as the hybrid seed."

very fair indication of the comparative vigor of each strain was obtained. Unfortunately crows and chipmunks played havoc with the "stand" in a number of cases, and accurate figures can not be given except in the following four cases where the stand was perfect.

A white dent, No. 8, yielded 121 bushels per acre (at 70 pounds per bushel); a yellow dent, No. 7, which had been inbred artificially for three years, yielded 62 bushels per acre; the cross between the two varieties, No. 7 × No. 8, yielded 142 bushels per acre.

Longfellow, No. 34, an 8-rowed, yellow flint, yielding 72 bushels per acre, was crossed with the same No. 8 white dent, yielding 121 bushels per acre; the resulting cross yielded 124 bushels per acre.

Sturges's hybrid, a 12-rowed, yellow flint with a tall, nonbranching stalk, partaking of the characters of dent varieties, was also crossed with No. 8 white dent. The flint parent yielded 48 bushels per acre, while the cross yielded 130 bushels per acre.

Two families of a yellow dent variety, which had each been inbred artificially for three years, were the parents of the fourth cross. No. 12, yielding 65 bushels per acre, was crossed with No. 7, yielding 62 bushels per acre. The F_1 generation yielded 202 bushels per acre. This last result is somewhat distorted, as five stalks per hill of the cross were allowed to grow, while of the parents only four seeds per hill were planted. About 90 per cent of the seeds produced mature stalks. Notwithstanding the closeness of planting to which this cross was subjected, however, casual observation was sufficient to show that it soared far beyond each parent in vigor of plant and size of ear.[a]

For ease in comparison Doctor East's results are here given in tabular form:

	Yield of female parent.	Yield of male parent.	Average yield of parents.	Yield of hybrid.	Percentage of increase over average of parents.
	Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Per cent.*
White dent × yellow dent	121	62	91.5	142	55
Yellow dent × white dent	72	121	96.5	124	28.5
Yellow flint × white dent	48	121	84.5	130	54
Yellow dent × yellow dent	65	62	63.5	*161	154

*This is the cross of which Doctor East states that five stalks per hill were allowed to grow instead of four, as in the case of the parents. The yield is here reduced by one-fifth from the original figure of 202 bushels to allow for the additional number of hybrid plants that were grown, although by this calculation the hybrid is placed at a disadvantage, due to the closeness of the planting.

It will be noted that the comparison with the parents was in this case very accurate, the plants representing the parents being grown from the identical ears that were used to make the crosses. The yield of one of the parents in the first cross and both the parents in the fourth had, however, been depressed by self-fertilization for three successive years. It is interesting to note in this connection that the introduction into a cross of an inbred strain yielding only one-half that of the other variety here results in increasing the yield above that of the high-yielding parent by over 17 per cent. Furthermore, the highest yield in the experiment was secured from a cross between

[a] East, E. M. The Distinction between Development and Heredity in Inbreeding. The American Naturalist, vol. 43, no. 507, 1909, pp. 178–179.

two inbred strains which without crossing were among those which gave the lowest yields of any represented in the experiment.

Regarding other crosses, Doctor East states:

> In the remainder of the field every possible combination of dent, flint, and sweet maize was grown, and in every case an increase in vigor over the parents was shown by the crosses. It is to be regretted that comparable yields could not be obtained in every instance, but, as a matter of fact, the differences were so apparent to the eye that it is almost unnecessary. The figures presented do not show the average increase to be expected by a cross. The manuring was heavy, the cultivation intensive, and the yields were beyond the ordinary. But they do show that in practically every case a combination of two high-bred varieties of seed corn is more vigorous than either parent.[a]

A NEW SERIES OF HYBRIDS BETWEEN DIVERSE TYPES.

The crosses thus far considered have in all cases been between strains that are comparatively closely related. The most violent crosses are among those reported by McCluer where varieties of sweet and dent, pop and dent, and sweet and pop corns were included. The diversity between these types may seem considerable, representing as they do the extremes of the types now cultivated in the United States, but looked at botanically these varieties appear closely related when compared with the very diverse types that exist in the Tropics.

Over the whole of the United States the interchange of seed has been so extensive and the culture is so nearly continuous that all characters are to a great extent shared by the whole series of varieties, even the most divergent types being distinguished by characters that differ in degree rather than in kind. Even before the advent of the white man the nomadic tendencies of the North American Indians must have operated against any complete isolation of types.

The sedentary habits of the Indians of tropical America are in strong contrast with those of the more northern tribes, and together with the great diversity of natural conditions have operated to produce an enormous number of very distinct types, showing numerous specialized adaptations to different conditions, the agricultural significance of which is only beginning to be appreciated.

As an instance of one of these divergent groups there may be mentioned a type of corn cultivated in parts of the lower plateau of Mexico in a region that receives such scanty rainfall that similar regions in this country would be thought entirely unsuited for corn growing. This corn is so different from the types with which we are familiar that it was given specific rank by Bonafous and named *Zea hirta*.[b] The leaf sheaths are densely covered with long hairs

[a] Op. cit., pp. 179–180.

[b] Bonafous, M. Annales des Sciences Naturelles, vol. 17, 1829, p. 156.

borne on tubercles, the leaves are few and very long and slender, the tassel is frequently unbranched, the spikelets are in groups of four or more instead of two, and the clusters are opposite each other instead of alternate. Even the root system is distinct from that of any of the common varieties of the United States, being spread out near the surface of the ground where the only available water is to be secured in the regions where this type is native. Many varieties inside this type differ among themselves much as the classes of flint, dent, and pop corns differ from each other. In fact, a closely similar series exists in this tropical type, there being varieties which judged by the ears, would be classed as flint and others as pop and dent corns.

While this type is one of the most distinct, many other tropical forms possess characters and habits that are entirely absent or only faintly indicated in United States varieties. Peculiarities of other tropical types will be mentioned in connection with the different crosses that are about to be described.

With a view to securing types adapted to sections of the country where United States varieties are unsuccessful, a considerable series of tropical types and varieties has been brought together. In the season of 1908 about 75 crosses were made among these tropical varieties, and also between them and several United States varieties. A number of these hybrids were grown in the summer of 1909 at Lanham, Md., a few miles from Washington, D. C. The parent varieties of 16 of these crosses were included in the plat and their behavior noted in comparison with the crosses. The experiment was considered as merely preliminary and but 16 hills of each variety were grown. While this number is altogether too small to be conclusive as a comparison of the values of the different crosses, the results as a whole are very significant as an illustration of the general value of first-generation hybrids. It becomes evident that the increase in vigor that earlier experiments have proved to be the rule with crosses of more or less closely related strains has also a very wide application among even the most primitive, unselected, and diverse types of corn. In 14 of the 16 crosses the yield exceeded the average of the parents. In 12 cases it exceeded the yield of either parent, the average increase for the whole series being about 53 per cent.

In the following brief account of the hybrids and their parents, the descriptions will for the most part be confined to the usually recorded characters of height, yield, and character of the ear, which data are sufficient to make the results of this experiment comparable with those previously reported. Detailed observations of the behavior of the parental characters in these and other hybrid combinations have been made, but are not needed for the purpose of this report.

Abnormalities will be briefly noted as a possible indication of the violence of the cross.

HYBRID AH 3, MARYLAND DENT BY HOPI.

Female parent.—An unselected white dent grown in Maryland. The particular plant used as the female parent was grown from the seed of a red ear. This proved to be the most prolific of the uncrossed strains; perhaps on account of its being the only locally grown variety in the experiment. No abnormalities were discovered in any part of the plant or in the ears. Average height, 6 feet 10 inches. The 16 plants grown produced 21 ears and 2 nubbins, weighing 19 pounds.

Male parent.—A variety grown by the Hopi Indians of Arizona. The most striking characteristics of the type are the very large male spikelets and enormous ear stalks. The color of the particular ear used in making the cross was a slaty blue. No abnormalities appeared in the plants grown in this experiment, though in Kansas this strain produced a number of ears with inverted grains, the embryo on the lower side, toward the base of the ear, and also a number of grains with double germs. Average height, 8 feet 10 inches. The 27 plants grown produced 21 ears and 2 nubbins, weighing 20 pounds.

Hybrid.—In spite of the fact that both of the parents yield pollen very abundantly, 6 of the 16 hybrid plants failed to produce pollen. No other abnormalities were observed. The plants were rather diverse, some resembling one parent and some the other. The ears, however, were as uniform as those of either parent and partook of the characters of both. Average height, 7 feet. The 16 plants grown produced 21 ears and 2 nubbins, weighing 20.1 pounds.[a]

HYBRID AH 4, TUSCARORA BY CINQUANTINO.

Female parent.—An 8-rowed soft variety, grown by the Tuscarora Indians of New York. The variety is early and suckers profusely, many of the suckers terminating in ears. Average height, 5 feet 8 inches. The 16 plants grown produced 14 ears and 10 nubbins, weighing 8.5 pounds.

Male parent.—A variety imported from Hungary under the name Pignoletto. A very small seeded, many-rowed type that would be classed as a pop, though unlike any of the American varieties of pop corn. This class of corn is known to the trade as "Cinquantino." The variety is small, without suckers, and very early. No abnor-

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[a] The yields of the hybrids and the parent varieties, reduced to pounds per plant, are brought together for comparison in Table IV, p. 29.

malities. Average height, 4 feet 4 inches. The 14 plants grown produced 14 ears and 1 nubbin, weighing 3.3 pounds.

Hybrid.—Plants and ears intermediate. No abnormalities. Average height, 6 feet 7 inches. The 15 plants grown produced 21 ears and 14 nubbins, weighing 11.3 pounds.

HYBRID DH 1, KANSAS DENT BY CHINESE.

Female parent.—A white dent developed by Mr. Elam Bartholomew, of Stockton, Kans. The variety has never been closely bred, but has been grown continuously for a number of years and kept up by selection of ears. No abnormalities. Average height, 7 feet 11 inches. The 29 plants grown produced 26 ears and 4 nubbins, weighing 28.6 pounds.

Male parent.—A variety of corn from China, with waxy endosperm, leaf blades borne on one side of the stalk, and silks produced in the angle of the leaf blades.[a]

The parent plant was grown from white seed separated from the imported mixture and had the erect monostichous leaf blades that characterize this variety. The second-year plants from American-grown seed showed these characteristics in a much less marked degree than those grown from imported seed. No abnormalities. Average height, 4 feet 7 inches. The 32 plants grown produced 46 ears and 9 nubbins, weighing 12.4 pounds.

Hybrid.—In the early stages the plants resembled the Chinese parent in having erect monostichous leaf blades, but this character was less marked later in the season. The plants remained dark green during a very dry season. The only indication of abnormality was the frequent production of pistillate flowers on the terminal inflorescences of the suckers. The ears were intermediate in size and appearance and as uniform as those of either parent. Average height, 6 feet 9 inches. The 16 plants grown produced 27 ears and 7 nubbins, weighing 17.5 pounds.

HYBRID DH 2, CHINESE BY CHIHUAHUA.

Female parent.—The same as the male parent of hybrid Dh1.

Male parent.—A starch variety from Chihuahua, Mexico. This variety is peculiar in having the longest leaf sheath at the top of the plant and in having the leaf sheaths covered with fine velvety hairs. No abnormalities. Average height, 8 feet 9 inches. The 14 plants grown produced 13 ears and 2 nubbins, weighing 9.7 pounds.

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[a] This variety is more fully described in Bulletin 161 of the Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, entitled "A New Type of Indian Corn from China."

Hybrid.—The plants of this cross exhibited greater diversity than was shown in any other cross. Two of the plants were so exactly like the female parent, both in plant and ear characters, as to arouse the suspicion that the precautions against foreign pollination had been imperfect and that the particular grains producing these plants were self-pollinated. This appears the more probable from the nature of the Chinese plants, which makes it especially difficult to exclude pollen from the tips of the silks that appear directly in the angles of the leaf blades. While the plants showed the complete range of the parental characters, the ears, with the exception of those noted above, were fairly uniform. One interrupted ear was produced; that is, a portion of the ear near the middle produced only staminate instead of pistillate flowers. Average height, 8 feet 3 inches. The 16 plants grown produced 25 ears and 18 nubbins, weighing 15.25 pounds.

HYBRID DH 3, HOPI BY CHINESE.

Female parent.—A plant from a white seed of the Hopi variety described as the male parent of hybrid Ah3.

Male parent.—White Chinese. The same as the male parent of hybrid Dh1.

Hybrid.—Plants fairly uniform, showing characters of both parents. Ears remarkably uniform, more nearly resembling the female parent. The only abnormal feature was the frequent exsertion of the ear beyond the husks. Average height, 8 feet 4 inches. The 16 plants grown produced 28 ears and 2 nubbins, weighing 20.4 pounds.

HYBRID DH 4, CHINESE BY XUPHA.

Female parent.—Plant from a white seed of Chinese similar to the male parent of hybrid Dh1.

Male parent.—A black, semistarch variety from Salvador. No abnormalities. Average height, 8 feet 8 inches. The 14 plants grown produced 21 ears and 5 nubbins, weighing 8.8 pounds.

Hybrid.—The hybrid ear from which these plants were grown was poorly matured. Plants and ears exhibited a number of abnormalities. Eight suckers and two main stalks bore small ears at the base of the tassel, below which were a number of supernumerary leaves. In two cases the margins of the leaf sheaths were grown together, forming a cylinder. About half of the ears produced staminate flowers; some were interrupted and many had a long staminal portion at the tip. Average height, 7 feet 10 inches. The 16 plants grown produced 18 ears and 18 nubbins, weighing 8.6 pounds.

HYBRID DH 6, BROWNSVILLE BY CHINESE.

Female parent.—A many-eared variety of white dent from Brownsville, Tex. The most striking peculiarity of this variety is the length of the husks, which extend far beyond the tip of the ear and are tightly closed. Although the ear from which these plants were grown was cross-pollinated, 9 seedlings out of 48 were albinos. The yield of this variety would have been slightly higher if the growing season had been longer, lower ears on many of the stalks being immature. The plants were rather weak rooted and fell badly before high winds. Average height, 9 feet 9 inches. The 15 plants grown produced 25 ears and 8 nubbins, weighing 11.6 pounds.

Male parent.—White Chinese similar to the male parent of hybrid Dh1.

Hybrid.—The plants showed few traces of the Chinese characters. The ears were not lacking in uniformity. Husk characters similar to the female parent. The full yielding power of this hybrid was not shown on account of early frosts. No abnormalities. Average height, 9 feet 6 inches. The 16 plants grown produced 35 ears and 17 nubbins, weighing 18.6 pounds.

HYBRID EH 1, HOPI BY ALGERIAN POP.

Female parent.—Same as the male parent of hybrid Ah3.

Male parent.—A type from Algeria with beaked grains that must be classed as pop corn. Its most pronounced peculiarities are the position of the ears, which are only 2 or 3 nodes from the top of the plant, and the nature of the pericarp, which is semiopaque but not colored. No abnormalities. Average height, 5 feet. The 16 plants grown produced 20 ears and 6 nubbins, weighing 5.5 pounds.

Hybrid.—Plants uniform and intermediate. The ears produced were quite unlike either parent, as large or larger than those of the female parent, but with very small grains. The only abnormalities were the production of ears at the base of the tassel on a few of the suckers, two "bears' foot" ears, and one branched ear. Average height, 9 feet 6 inches. The 15 plants grown produced 21 ears and 5 nubbins, weighing 13.6 pounds.

HYBRID GH 2, TOM THUMB BY QUEZALTENANGO BLACK.

Female parent.—A very small variety of pop corn. The plants are from 8 inches to 2 feet in height and bear diminutive ears about 2 or 3 inches long. No abnormalities. The 6 plants grown produced 7 ears, weighing 0.6 pound.

Male parent.—A very tall variety from the high mountains of the western part of Guatemala. The ears are borne very near the top of the plants and are consequently late in maturing. Although apparently an unproductive type the yield here given is little indication of what the variety might do if the season permitted maturing. The cross was made to test the possibility of making crosses between varieties that represented the extremes in size. Average height, 9 feet 6 inches. The 15 plants grown produced 9 nubbins, weighing 1.5 pounds.

Hybrid.—Plants intermediate but exhibiting considerable irregularity in size. Ears averaging 7 inches long, fairly uniform. The principal abnormality was shown in the leaves, which were crumpled and distorted in all the plants. The color was so dark as to be abnormal. While this cross showed distinctly an increase in vigor over that of the parents, the yield of both parents was so small that the amount of the increase should not be considered. Average height, 6 feet 7 inches. The 15 plants grown produced 16 ears and 6 nubbins, weighing 6.25 pounds.[a]

HYBRID KH 31, BROWNSVILLE BY GUATEMALA RED.

Female parent.—The same as the female parent of hybrid Dh6.

Male parent.—A red flinty-seeded variety with 12 to 16 rowed ears, from the lowlands of Guatemala. No abnormalities. Average height, 8 feet 11 inches. The 14 plants grown produced 6 ears and 12 nubbins, weighing 4.31 pounds.

Hybrid.—Ears fairly uniform. Plants and ears without abnormalities. Average height, 10 feet 2 inches. The 32 plants grown produced 29 ears and 10 nubbins, weighing 15.6 pounds.

HYBRID KH 62, GUATEMALA RED BY SALVADOR BLACK.

Female parent.—The same as the male parent of hybrid Kh31.

Male parent.—A black variety from Salvador not unlike the female parent. Two plants of this variety produced branched ears. The ear stalks also curved up instead of down, so that the ears crossed the main stem. The 15 plants grown produced 3 ears and 12 nubbins, weighing 4.1 pounds.

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[a] East states "I have repeatedly tried to cross Giant Missouri Cob Pipe maize (14 feet high) and Tom Thumb pop maize (2 feet high), but have always failed. They both cross readily with varieties intermediate in size, but are sterile between themselves." (See East, E. M., A Mendelian Interpretation of Variation that is Apparently Continuous, The American Naturalist, vol. 44, 1910, p. 82.

It may also be noted that this small variety was successfully crossed with a large Mexican dent whose average height was 11 feet 7 inches. In these experiments the Giant Missouri Cob Pipe corn averaged only 8 feet 4 inches.

Hybrid.—Ears very irregular. One plant produced 2 ears, both of which were interrupted. In many others the ears exceeded the husks. The 16 plants grown produced 8 ears and 8 nubbins, weighing 5.25 pounds.

HYBRID MH 13, QUARENTANO BY BROWNSVILLE.

Female parent.—A drought-resistant variety from Chiapas, Mexico. Many of the plants of this variety have very wide leaf sheaths that are closely wrapped around the weak stalk and are the chief support of the upper part of the plant. Average height, 7 feet 6 inches. The 16 plants grown produced 8 ears and 7 nubbins, weighing 4.3 pounds.

Male parent.—The same as the female parent of Dh6.

Hybrid.—Plants and ears very diverse, without the peculiarities of the female parent. Nine of the plants produced ears exceeding the husks. In three cases the ears were interrupted. The inner husks were crumpled at the base of the ear, a not uncommon condition with thick-husked varieties. Average height, 11 feet 5 inches. This is one of the two cases where the yield of the hybrid was below the average of the parents. With such disparity between the yields of the two parents this may mean that the hybrid more nearly resembled the lower yielding parent. The 16 plants grown produced 11 ears and 7 nubbins, weighing 7.6 pounds.

HYBRID MH 15, HUAMAMANTLA BY HAIRY MEXICAN.

Female parent.—A drought-resistant variety with shoe-peg grains, from Mexico. A variety of the hairy Mexican series, though not a pronounced type. The tassels have a few very long primary branches. The season the cross was made this variety had 50 per cent of the ears interrupted. Plants grown from the same original seed in the season of 1909 had no interrupted ears. Average height, 8 feet. The 13 plants grown produced 4 ears and 7 nubbins, weighing 5.2 pounds.

Male parent.—A pronounced type of the hairy Mexican series, with superficial roots, hairy leaf sheaths, and usually unbranched tassels. The poorly protected ears usually decay in the moist fall weather. Average height, 7 feet 11 inches. The 16 plants grown produced 5 ears and 4 nubbins, weighing 2.8 pounds.

Hybrid.—Plants irregular, exhibiting nearly the full range of both parents. The stalks were rather weak; the tassels with from 3 to 7 branches. One ear was produced with a staminate portion at the tip. Average height, 9 feet 1 inch. The 15 plants grown produced 7 ears and 9 nubbins, weighing 4.6 pounds.

HYBRID MH 16, ARRIBEÑO BY HAIRY MEXICAN.

Female parent.—Similar to the female parent of Mh15, but a larger variety. Average height, 9 feet. The 15 plants grown produced 10 ears and 7 nubbins, weighing 5.8 pounds.

Male parent.—Same as the male parent of hybrid Mh15.

Hybrid.—Plants similar to hybrid Mh15, but more robust and uniform. A striking characteristic of this cross was that the leaf blades, though slightly shorter, were much broader than those of either parent. The fifth blade of the hybrid averaged 31.3 by 5.6 inches. The corresponding blade of the female parent averaged 35.4 by 4.1 and the male 31.5 by 4.7 inches. Average height, 9 feet. The 14 plants grown produced 9 ears and 7 nubbins, weighing 6.6 pounds.

HYBRID MH 17, HAIRY MEXICAN BY CHINESE.

Female parent.—The same as the male parent of hybrid Mh15.

Male parent.—The same as the male parent of hybrid Dh1.

Hybrid.—Plants and ears fairly uniform. One difference between the parent strains is that in the female parent when more than one ear is produced at a node the secondary ear is borne directly in the axil of the prophyllum. The male parent resembles the United States varieties in having the first secondary ear borne in the axil of the first husk. Of the hybrid plants that produce secondary ears one-half resembled the male and one-half the female in this respect. The only abnormalities noted were a tendency in a number of plants to have the leaves on the upper part of the plant crowded and one ear with a staminate spike at the tip. Average height, 7 feet 4 inches. The 16 plants grown produced 18 ears and 4 nubbins, weighing 9.8 pounds.

HYBRID MH 25, MEXICAN DENT BY TOM THUMB.

Female parent.—A large Mexican variety with a pronounced tendency to produce large secondary ears. One interrupted ear was produced. Average height, 11 feet 7 inches. The 15 plants grown produced 10 ears and 15 nubbins, weighing 7.8 pounds.

Male parent.—The same as the female parent of hybrid Gh2.

Hybrid.—Plants resembling the female parent in most particulars. About one-half the ears exceeded the husks. Average height, 6 feet 7 inches. The 16 plants grown produced 22 ears and 13 nubbins, weighing 8.6 pounds. Though this cross would seem to have been quite as violent as Gh2, no pronounced abnormalities were found.

YIELDS OF FIRST-GENERATION HYBRIDS.

The following table shows the behavior of the 16 crosses and their parents. The yields are given as yield per plant and were calculated

by dividing the total weight of the ears produced in the row by the number of plants. The plants were started four in a hill and thinned to one as soon as established.

TABLE IV.—*Yields per plant of 16 corn hybrids compared with that of their parents.*

Name of hybrid.	Yield of female parent.	Yield of male parent.	Average yield of parents.	Yield of hybrid.	Percentage of increase of hybrid over average of parents.
	Pounds.	*Pound.*	*Pound.*	*Pounds.*	*Per cent.*
Ah3, Maryland dent by Hopi	1.19	0.74	0.965	1.25	29
Ah4, Tuscarora by Cinquantino	.53	.24	.385	.75	95
Dh1, Kansas dent by Chinese	.99	.39	.690	1.09	58
Dh2, Chinese by Chihuahua	.39	.69	.540	.95	76
Dh3, Hopi by Chinese	.74	.39	.565	1.28	126
Dh4, Chinese by Xupha	.39	.63	.510	.54	6
Dh6, Brownsville by Chinese	.77	.39	.580	1.16	100
Eh1, Hopi by Algerian pop	.74	.34	.540	.91	69
Gh2, Tom Thumb by Quezaltenango black	.10	.10	.100	.42	(a)
Kh31, Brownsville by Guatemala red	.77	.31	.540	.49	−9
Kh62, Guatemala red by Salvador black	.31	.27	.290	.33	14
Mh13, Quarentano by Brownsville	.27	.77	.520	.48	−8
Mh15, Huamamantla by Hairy Mexican	.40	.18	.290	.31	7
Mh16, Arribeño by Hairy Mexican	.39	.18	.285	.47	65
Mh17, Hairy Mexican by Chinese	.18	.39	.285	.61	114
Mh25, Mexican dent by Tom Thumb	.52	.10	.310	.54	(a)
Average percentage of increase of hybrids over average of parents					53

a Where the yield of either parent fell as low as 0.10 pound per plant the percentage of increase of the hybrid is omitted. In dealing with these small quantities it is believed that percentages would be misleading.

Before leaving the subject of increased yields in first-generation hybrids it may be well to summarize the results of the experiments bearing on this question.

To carefully canvass the literature of agriculture for all references to the yield of first-generation hybrids would be a large undertaking, and it is not pretended that the present summary is complete. It is believed, however, that the experiments cited, which are all that have come to the writer's attention, establish the wide application of the principle and give a fair indication of its importance.

Beal (Michigan, 1878–80) in two crosses very carefully compared with the parent varieties secured an increase in both cases, the average increase being 31 per cent.

Another cross by Beal (1882) compared with the best parent exceeded that parent by 21 per cent.

Ingersoll (Indiana, 1881) in a cross between two strains of the same variety secured an increase over the male parent of 95 per cent.

Sanborn (Maine, 1889) in one cross secured an increase over the average of the parents of 41 per cent.

Morrow and Gardner (Illinois, 1892) secured increases in eight out of nine crosses, the average increase being 11 per cent.

Shull (New York, 1908) by first inbreeding and then crossing got an increase over the original mixed stock of 2 per cent.

East (Connecticut, 1908) secured increases in all of four crosses, the average increase being 73 per cent.

Experiments by the writer with primitive types crossed with one another and with United States varieties, first reported in the present paper, gave increased yields in 14 out of 16 cases, the average increase being 53 per cent.

Though the average of the yields of the parent varieties may be considered as a fair standard for judging the increased yields of the hybrids from the standpoint of heredity, the practical value of hybrids must be determined by comparing their yields with those of the more productive parents. To secure evidence on this point it will be necessary to consider the crosses which have been made between good-yielding varieties grown under favorable conditions, excluding those in which there is great disparity in the yields of the parents.

The following table includes all the crosses here reported in which the parents appear to have been fair-yielding standard varieties giving approximately the same yields.

TABLE V.—*Increased yield of hybrid corn over the more productive parent.*

	Percentage of increase of hybrid over better parent.
Beal (p. 11). "Varieties essentially alike"	51
Beal (p. 11). "Varieties essentially alike"	10
Beal (p. 12). Hybrid compared only with better parent	21
Ingersoll (p. 12). Strains of the same variety	95
Morrow and Gardner (p. 15). Parents differed by 2.6 bushels per acre	0
Morrow and Gardner (p. 15). Parents differed by 15.0 bushels per acre	—8
Morrow and Gardner (p. 15). Parents differed by 8.5 bushels per acre	17
Morrow and Gardner (p. 15). Parents differed by 13.0 bushels per acre	4
Morrow and Gardner (p. 15). Parents differed by 5.8 bushels per acre	18

It will be seen from Table V that in six of the nine crosses significant increases were obtained over the yield of either parent, and two of the three exceptions should, perhaps, have been excluded, since the differences between the yields of the parents were 15 and 13 bushels, respectively.

The experiments thus far reported are too few to warrant any conclusions regarding the nature of the crosses which may be relied upon to yield the greatest increase. It is naturally to be expected that the percentage of increase will be greatest between low-yielding strains, but the greatest increase in bushels per acre may follow the crossing of the more highly developed strains.

Probably none of the crosses here considered were between carefully bred and locally adjusted strains. What the results of such crosses will be is yet to be determined. Since the most carefully selected strains are more or less inbred, a substantial increase would be expected from crossing two such unrelated inbred strains unless they have already approached the limit of production of the corn plant.

Experiments similar to those conducted by Shull may have a special bearing in this connection. The reduction in vigor which accompanies the inbreeding to which his strains are subjected would have an effect similar to growing the plants under adverse conditions and would tend to eliminate all but the strongest individuals. This would, in fact, constitute an effective form of selection, and with such strains thrown into the vigorous condition of first-generation hybrids a maximum performance might be expected.

While the best results may in general be expected from crossing two varieties both of which are productive, crossing with a low-yielding variety may operate to increase the yield above that of a much higher yielding variety with which it is crossed. The Chinese variety mentioned on page 23 is a small variety producing only 0.39 pound per plant in the experiments reported. Yet in four of the five cases where this variety was crossed with higher yielding varieties the yield of the hybrid exceeded that of the variety with which it was crossed. The average yield of the five varieties with which the Chinese corn was crossed was 0.764 pound per plant, nearly double that of the Chinese, yet the average yield of the five hybrids was 1.004 pounds per plant, an increase over the highest yielding parent of nearly 33 per cent. If the increased vigor of hybrids is in any way associated with the distinctness of the parent types, the remarkable behavior of this series of crosses may perhaps be understood. This Chinese variety is one of the most divergent types and must have been isolated from all ordinary types of corn for a very long time. Evidence was presented in a former publication[a] that the introduction of corn in China was probably pre-Columbian. In these and other crosses where low-yielding varieties producing more than one ear to the plant operated to increase the yield of larger-eared types, the greater yields appeared to have been brought about by an increase in the number of ears with only a slight reduction in their size.

EXTENSION OF CORN CULTURE BY FIRST-GENERATION HYBRIDS.

In addition to increased yield in corn-growing regions the vigor of first-generation hybrids may also allow of an extension of corn growing beyond the present area of production.

Even a slight increase in the drought resistance of corn would make possible the extension of corn culture into large regions where the growing of this crop is now too precarious to justify the effort. The subject is of such importance as to warrant the investigation of every possibility.

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[a] A New Type of Indian Corn from China, Bulletin 161, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, pp. 20–24.

That the utilization of first-generation hybrids will be found of special value in the drier parts of the country was clearly indicated by the behavior of the hybrids described in these pages.

The season during which these hybrids were grown was one of exceptional drought, affording an excellent opportunity for observing the drought-resisting ability of the different strains and their hybrids. The rainfall at Washington, D. C., for April, May, and June was slightly below the average, and for July and August it was 4.07 inches, less than one-half the normal.

The series included varieties from localities with such extremes of climate as obtain in the plateau region of Mexico and the moist Tropics of the lowlands of Central America. While the differences between the varieties in their ability to withstand drought were obvious, the most striking differences of this kind were between the hybrids and the pure strains. Almost without regard to the nature of the parents the hybrids remained dark green and vigorous when nearly all of the pure strains were giving evidence of the lack of moisture by their curled leaves and yellow color. This ability to withstand drought may have been a factor in the increased yields which the hybrids produced.

Experiments are being made with a series of hybrids in western Kansas and the dry Southwest with the idea of learning which crosses will prove best suited to these extreme conditions.

Experiments at the Virginia Agricultural Experiment Station indicate that first-generation hybrids may be found to withstand excessive moisture as well as drought. While the crosses were apparently undertaken with the idea of establishing hybrid varieties, the results so far as reported apply only to the first generation.

> The native varieties that were crossed with the western corns have developed three or four good strains, and out of some 350 samples tested here this year none have stood the wet season and made as good yields as the improved strains obtained by crossing pure-bred western corn with our best native varieties.[a]

Associated with the general increase in vigor in first-generation hybrids a certain measure of disease resistance may naturally be expected. Many plant diseases that are unable to attack vigorous plants are able to do serious damage to weaker varieties or to plants that are weakened by adverse conditions. The ability of the hybrids to resist drought might at the same time protect them against disease.

In the case of the corn smut, which was the only disease that affected any of the experiments, this factor of disease resistance does not appear to apply, for the attacks of the smut do not seem to

[a] Vanatter, Phares O. Annual Report, Virginia Agricultural Experiment Station, 1906, p. 55.

depend upon the vigor of the plants. Nothing approaching immunity to this disease has been observed in any of the varieties or the hybrids.[a]

FIRST-GENERATION HYBRIDS AND CENTRALIZED SEED PRODUCTION.

It is coming to be generally recognized that in corn culture the use of seed not produced locally is a bad practice, and this is especially true of the most carefully selected varieties. The stimulus to the production of high-grade strains of corn is seriously weakened by the extremely circumscribed area in which such strains can be grown advantageously without further selection. Men of exceptional skill and experience who devote their whole time to the development of improved strains can, without doubt, do more effective work in selection than the farmer who is pressed with other work. But as soon as a carefully selected strain is placed under conditions different from those under which it was developed it behaves in a more or less abnormal manner, and appears at a disadvantage when compared with locally adjusted varieties. This factor of local adjustment is so important that if carefully selected strains are to be directly utilized in commercial production the centralization of seed growing must be discouraged. Farmers must be urged to select their own seed or to secure it from a local breeder.

That first-generation hybrids are relatively free from the new-place effects that so seriously interfere with the spread of varieties has not been demonstrated in corn, but may confidently be expected from the analogy of first-generation hybrids in other crops.[b] This does not mean that a given cross will do equally well in all parts of the country, but that it will make little difference whether the crossing is done in one part of the country or another. When it is once ascertained which combination of varieties is best adapted to a particular locality, pure seed of these varieties may be maintained and the crosses made under the supervision of a trained plant breeder at a central station.

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[a] It was repeatedly observed that plants affected with smut were darker green and more vigorous than neighboring plants not affected. This difference was noticed especially in a strain that had been reduced in vigor by self-fertilization. In this case but one plant in the row was affected with smut, and the stalk of this plant measured 3.82 inches in circumference, while the largest of the healthy plants measured only 3.15 inches. The leaves were also broader and dark green, while all the other plants were yellow and spotted.

Except for the deformed parts where the fungus fruited, the smutted plant appeared more nearly normal than any of the others. The presence of the fungus seems in some way to restore the vigor lost through self-fertilization.

[b] Cook, O. F. Local Adjustment of Cotton Varieties. Bulletin 159, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909.

Careful seedsmen who wish to extend the range of territory to which they can supply seed that will be equal or superior to the best locally selected seed should be willing to give careful consideration to the possibility of establishing regular supplies of first-generation hybrid seed for their customers.

FIRST-GENERATION HYBRIDS IN SWEET CORN.

While the production of sweet corn is influenced by very different considerations from the production of field corn, the evidence at hand indicates that the advantages of first-generation hybrids apply to sweet corn with even greater force than to field corn.

In sweet corn, as with field corn, the yield is an important item, and the experimental data here presented warrant the statement that the yield can be very materially increased by means of first-generation hybrids.

With sweet corn, however, the yield is not the only consideration; quality and uniformity are important factors that must be taken into consideration. As regards quality, the evidence indicates that in most cases it will be intermediate between that of the parents. If parents of good quality are chosen, the quality of the hybrid will be satisfactory. The proof of this rests not alone on the few cases where the quality of the first generation of crosses of sweet-corn varieties has been recorded, but on the general fact that the morphological characters of the first generation of crosses in corn are almost always intermediate between those of the parents. With respect to uniformity it may be said that experiments in crossing sweet varieties have not been recorded in such a way as to give direct evidence. On the other hand, experiments in the crossing of field corns make it certain that in this class, with properly chosen varieties, a perfectly satisfactory degree of uniformity can be secured. The first generation of a cross is usually quite as uniform as the parent strains, a condition naturally to be expected in view of the general tendency for all morphological characters to appear intermediate in the first generation. While the strict uniformity required in score-card ratings may not be assured, it is altogether probable that the uniformity of size, color, shape, and time of maturing required by the market will be fully met if reasonably uniform strains are selected as parents.

The important differences between sweet and field corn in the commercial methods of producing and handling seed are all of a nature to make the application of this principle more effective with sweet corn than with field corn. A much larger percentage of sweet-corn than of field-corn growers buy their seed, a practice that is much to be regretted where pure strains are used, since the lack of

local adjustment interferes with the proper performance of superior and carefully selected strains, even when the seed is carried only a short distance. First-generation hybrids are to a great extent independent of this delicate adjustment to local conditions. The utilization of first-generation hybrids would tend to obviate the necessity of urging each farmer to breed his own sweet corn, a practice which must surely follow if the highest performance of pure strains is to be secured.

The possibility of growing combinations of highly bred strains over wide areas would enable the work of the few really skilled breeders of sweet corn to be much more effective. While the general principle is very simple and of wide application, its fullest utilization will require a large amount of experimentation to determine the best combinations for each locality and market. A thorough knowledge of the existing varieties would be of the greatest value to anyone undertaking this work, and, as the cross has to be made anew each year, the inventor of a new and superior combination could much more effectively guard his discovery and secure a more adequate reward for his work than is possible to the breeder of a pure strain.

While further experiments are needed to establish the assumption that crosses of sweet-corn varieties will behave essentially the same as crosses of varieties of field corn, the following possibilities of first-generation hybrids are definitely indicated: (1) Increased yield, (2) uniformity equal to that of the parents, (3) quality intermediate between the parents, (4) increased immunity from disease, (5) extension of the industry into new territory, (6) less localization of highly bred strains, (7) increased utilization of the work of experienced breeders, and (8) stimulus to the work of improvement through the possibility of protecting new productions.

METHODS FOR TESTING CORN HYBRIDS.

It is hoped that the present summary of facts and possibilities regarding first-generation hybrids will assist in stimulating experiments, especially by those who are in a position to keep careful records and report the results.

The experiments are of such a simple nature and results may be expected in such a relatively short time that those interested in increased yields should be concerned to learn the possibilities of this method for their particular localities and varieties and to report the results of their experiments as a contribution to the better understanding of the principles involved. Exceptions are to be expected, though none that may not be ascribed to experimental error have yet been reported.

From the standpoint of the investigation the failures of such experiments are often of even greater interest than the successes, since they may lead to better understandings of the factors involved.

In reporting results it would seem desirable to state the facts bearing upon as many of the following points as possible:

(1) *Names and descriptions of varieties crossed.*—While the names of commercial varieties are almost hopelessly confused, some designations are necessary for purposes of reference, and if these are accompanied by careful descriptions many errors may be avoided, as well as a needless duplication of work.

(2) *History of the varieties.*—This should be traced as far back as possible to throw light on the degree of relationship that exists between the varieties crossed.

(3) *Sources of seed and previous methods of breeding.*—Important differences may be expected even where the same varieties are used, depending on whether the seed has been self-pollinated or cross-pollinated; also whether it was the result of mass selection in the field or crib or was derived from a single ear.

(4) *Size of the hybridizing plat and the plats or rows in which the yields are tested.*—The ratio between the area devoted to each variety in the breeding plat and that in which the yield test of the same variety is made should be recorded, since it is a measure of the opportunity for selection. If the breeding or hybridizing plat is small in proportion to the area to be planted, it will be necessary to save a large part of the seed for planting and the opportunity for selection will be correspondingly small. The failure to take this fact into consideration is one of the reasons why large field plantings of pure-bred varieties so frequently fail to meet expectations of high yields indicated in the breeding plats, where a more rigid selection was practiced.

(5) *Extent of self-pollination in the parent varieties.*—Many varieties produce pollen so little in advance of the silks that a considerable proportion of the seed is self-pollinated, and this operates to diminish the yield of the resulting plants. In such cases a part of the increase that might be ascribed to the crossing of two varieties would in reality be due to the depressed yields of the parent varieties with which the cross is compared. To determine the increase actually due to the crossing, seed from detasseled plants of the parent varieties should be included in the yield test, together with ordinary wind-pollinated seed of the same varieties.

(6) *The method by which the yields are compared and the precautions against experimental error.*—In this connection it should be borne in mind that large plats do not insure greater accuracy. The larger the plat the greater the difficulty of obtaining equal conditions.

Much greater accuracy can be secured by a comparison of a series of single rows or narrow plats and repeating the series as many times as space or seed will permit.

DIFFERENT METHODS OF PRODUCING HYBRID SEED.

While the process of securing hybrid seed is very simple, it is possible to vary the details of the method to suit different objects and conditions. Those wishing to experiment with a considerable series of hybrids will find it convenient to select what is considered the most promising variety for the male parent and plant this variety in every other row. Any number of other varieties can then be planted in the alternate rows and carefully detasseled. Hybrids will then be secured between the variety selected as a male parent and each of the others, and the seed will be in sufficient quantity to make accurate yield tests the following season.

If it is desired to keep accurate pedigrees of individual plants, resort must be had to hand pollination.

The production of hybrid seed on a commercial scale also permits of considerable variety in the details of the method. Whatever method is followed it would seem desirable that the plat in which the hybrid is made be large enough to afford opportunity for selection. The actual size of the seed plat should be governed by the size of the field planting to be made the following season and the ratio should not be greater than 1 to 100. Thus, if the contemplated field planting is to be 50 acres the hybridizing plat should not be less than half an acre.

Perhaps the most simple method for the farmer is to purchase each year a small quantity of seed of two varieties that are known to be well adapted to the particular section and plant in alternate rows in a hybridizing plat, as recently recommended by Doctor East.[a]

The varieties must, of course, be of nearly the same length of season, and in case of any difference in this respect the variety that flowers early should be chosen for detasseling. If the farmer wishes to grow his own parent varieties he can do so by alternating the male and female parents each succeeding year and selecting enough seed from the variety not detasseled to supply the hybridizing plat for two years, the first year as the female parent and the following year as the male. The same result could be approximated by detasseling one of the varieties in one half of the field and the other variety in the other half of the field. By this method seed of both varieties would be secured each year, but considerable indiscriminate crossing would take place.

[a] The Rural New Yorker, May 1 and 8, 1909.

One difficulty, however, with this reciprocal use of male and female parents would arise unless the varieties agree in length of season. No difficulty would be experienced in securing perfect pollination in a short-season variety used as the female parent, but if such a variety were expected to serve as the male parent the tendency to the early shedding of the pollen might leave little or none available for fertilizing a later variety used as a female parent.

The following directions, which have been sent out to several cooperative experimenters, give a concrete example of one of the ways in which the value of first-generation hybrids may be determined:

Experiments as outlined below involve the use of two varieties and two separate plats. Varieties may be designated as No. 1 and No. 2, the plats as A and B. The plats should be sufficiently separated to prevent cross-pollination between them.

It should be kept in mind that the increased yield can be expected only for the one year immediately following that in which the cross is made.

Plat A is planted with alternate rows of No. 1 and No. 2. The rows planted with No. 2 are to have all plants detasseled. The crop of No. 1 and No. 2 is to be saved separately.

Plat B is planted entirely with variety No. 2 and has alternate rows detasseled. The crop from the tasseled and detasseled rows is to be saved separately.

At harvesting there will be the following lots of seed:

(1) Plat A. Variety No. 1, field-pollinated.
(2) Plat A. Hybrid between No. 1 and No. 2.
(3) Plat B. Variety No. 2, field-pollinated.
(4) Plat B. Variety No. 2, cross-pollinated.

The yields in the year the cross is made should show the comparative value of the two varieties and the effect, if any, of detasseling on the immediate yield.

A comparison of the yield from these four lots of seed the following year should show the yield of the first-generation hybrid as compared with the pure varieties and to what extent the increase, if any, is due to the elimination of self-pollinated seed.

If plat B can not be provided, seed of variety No. 2 should be held for planting the following year in comparison with variety No. 1 and the hybrid seed.

If it is considered important to have the crop of a uniform color, yellow and white varieties should not be crossed, for the grains will be of different colors in the year following the cross. Crosses between dent and flint or between these and sweet corn would also result in a lack of uniformity with respect to the character of the seed. That such differences should occur while the other characters remain so nearly uniform may appear remarkable, but is explained by another of the peculiar habits of the corn plant. Unlike most other plants the seeds of corn show an immediate effect of pollen (xenia).[a] If a white-seeded variety is crossed by one with yellow or black seeds, the new seeds that are produced show the color of the male parent.

[a] For a discussion of xenia, see Webber, H. J., Bulletin 22, Division of Vegetable Physiology and Pathology, U. S. Dept. of Agriculture, 1900.

The embryo that forms as a result of a cross-pollination is, of course, hybrid in nature and may differ from the female parent. Owing to a peculiar double fertilization that obtains in corn the developing endosperm as well as the embryo is contributed to by the pollen and may resemble the male parent. With respect to the characters of the endosperm we are already dealing with the first generation of a hybrid and the general law of uniformity in the first generation seems to hold in most instances. There may be no predicting what the nature of the grain will be, but those plants resulting from the same cross may usually be depended upon to be alike.

The diversity that appears in the seed color of first-generation hybrids is only an apparent exception to the general rule of uniformity in first-generation hybrids. The endosperm in which this diversity appears is in reality the second generation of the hybrid and may consequently show the diversity characteristic of second-generation hybrids.

CONCLUSIONS.

The corn plant is naturally cross-fertilized and requires the stimulus of crossing to produce maximum yields. Methods of close breeding that can be applied to other crops with advantage do violence to the nature of the plant and tend to reduce the vigor of growth and the yield of grain.

As a result of the peculiar habits of reproduction of the corn plant, the raising of hybrid seed does not require any special skill or any large increase of labor. The cost involved is insignificant in comparison with the increased yields that are obtained.

No reason is apparent why the vigor of hybrids may not be regularly utilized to increase the yields of the corn crop. A refusal to take this factor into account would be like rejecting the use of commercial fertilizers or failing to take advantage of the increase that may be obtained by selective breeding.

The planting of first-generation hybrid seed as a method of securing a larger crop is to be considered as entirely distinct from the idea that superior varieties can be bred by hybridizing or crossing. Crosses between distinct varieties or strains at once increase the yield, but to maintain this high performance the cross must be made anew each year.

Experiments to determine the value of first-generation hybrids have been made at various times since 1878, but in an isolated and disconnected manner and usually without any adequate appreciation of the possibilities of this method as a regular element of farm practice.

In the literature which has thus far been examined, 19 crosses have been reported. With a single exception these hybrids gave larger

yields than the average of the parents, the amount ranging as high as 95 per cent. The series includes experiments in six different States and embraces a wide range of varieties.

Similar increases are here reported in crosses between the members of a new series of types of corn from China, Africa, and the American Tropics, very different from United States varieties and very unlike among themselves. These experiments show that a very wide application of this principle is possible.

In addition to increased yields there is reason to believe that the increased vigor of first-generation hybrids may become an important factor of adaptation to different conditions of growth. The hybrids appear not to require the delicate adjustment to local conditions necessary to the proper performance of pure strains. The utilization of hybrids may be expected to extend the range of utility of the high-yielding types beyond the present range of adaptation of such varieties.

First-generation hybrids are a distinct factor in the problem of securing varieties of corn with adaptations that fit them for special conditions. The increased vigor which these hybrids possess should make possible their growth in regions where pure strains fail and should also provide some measure of disease resistance.

The advantage of crossing distinct varieties is equally applicable to the improvement of sweet corn and affords a measure of protection to those discovering new and valuable combinations.

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